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(54) Forming an erosive jet

(57) An erosive jet for hydraulic mining is formed by supplying an aqueous abrasive slurry through a tube to an exit and water through a convergent pipe coaxial with and surrounding the slurry tube. The slurry tube projects in front of the water pipe, saving wear. The slurry tube exit may have many parallel or convergent orifices.

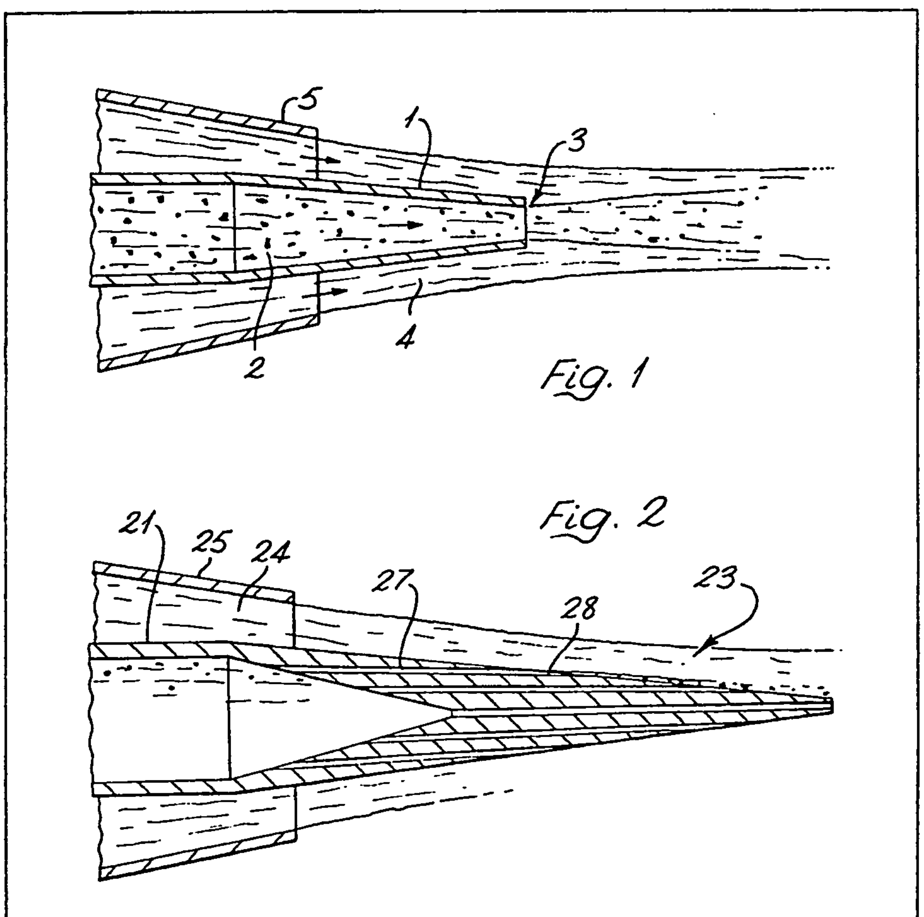

Fig. 1
Fig. 2

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The drawing originally filed was informal and the print here reproduced is taken from a later filed formal copy.

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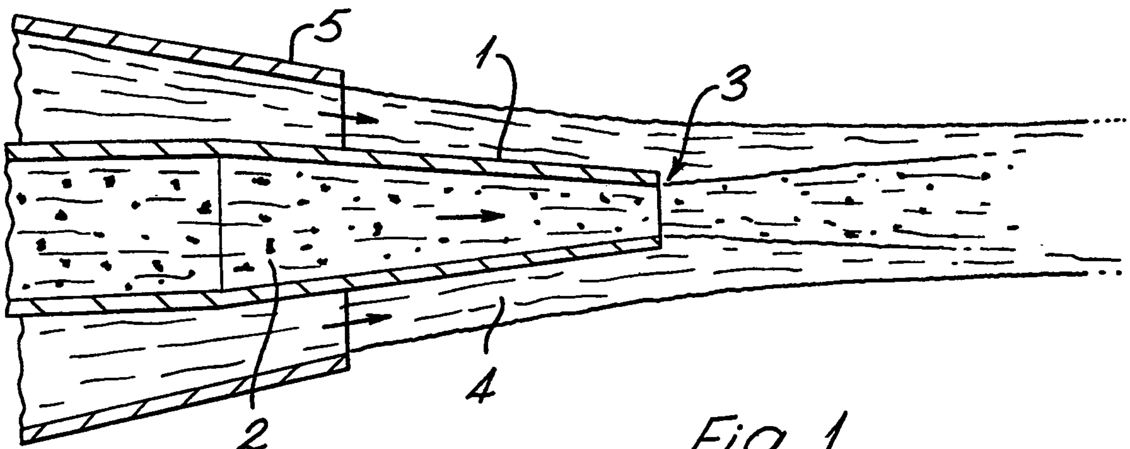
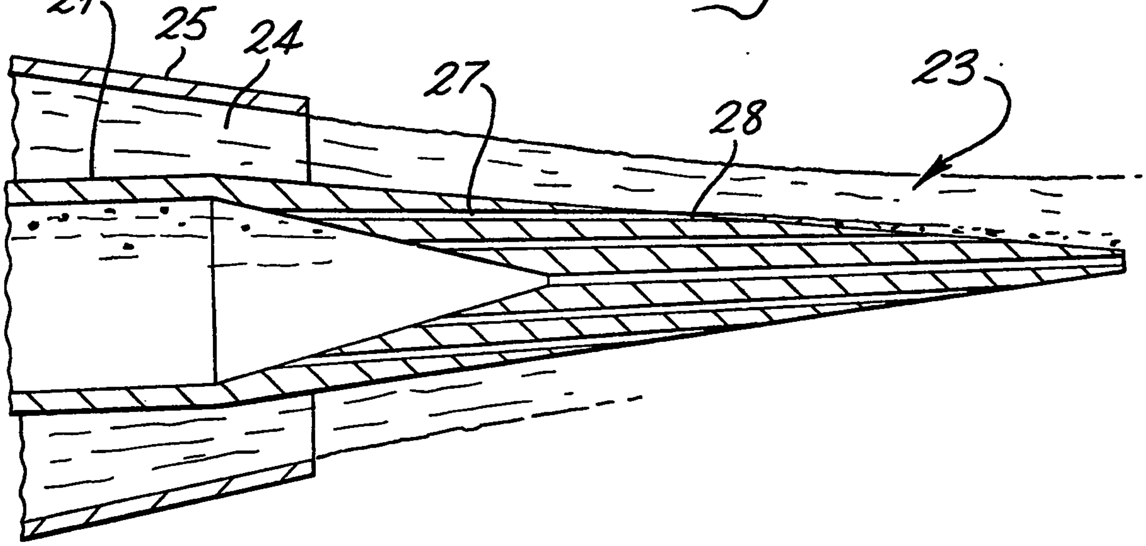


Fig. 1

Fig. 2



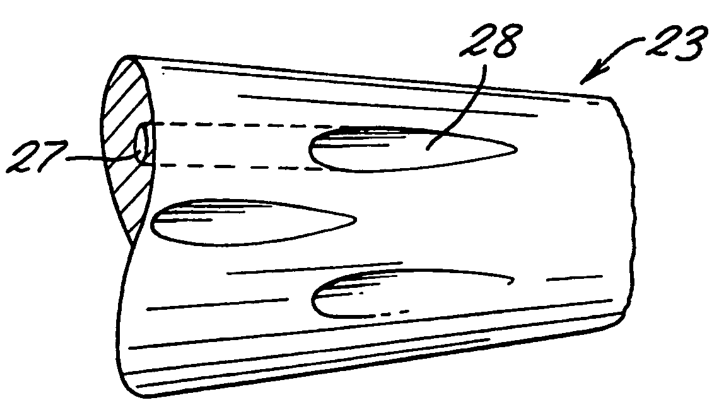


Fig. 3

SPECIFICATION

Forming an erosive jet

This invention relates to a method of forming an erosive jet, typically for use in a hydraulic erosion method, usually for tunnelling, mining or related purposes.

A known method of boring rock involves adding an abrasive to a stream of water pumped under pressure at high speed to a nozzle at the point of advance. An improvement described in GB Patent Specification 230078 (1925) suggests that a grinding medium be introduced through an orifice into a converging pipe leading to an outlet nozzle. Water under pressure is being pumped through the pipe. As the orifice debouches in the same direction as the water flow, the stream of water carries away and accelerates the grinding medium to form an erosive hydraulic jet discharging at the outlet nozzle.

A disadvantage with the known method, and possibly even with the improvement, is that the abrasive stream erodes the nozzle and that the grinding medium has to be supplied at a high pressure comparable with the water pressure, otherwise it is not entrained into the jet without inducing severe instabilities into the jet.

According to the invention, a method of forming an erosive jet comprises supplying a first material through a tube to an exit, directing a second material in the same sense as the first material through a convergent pipe generally coaxial with and surrounding the tube, at least one of the materials being a fluid, the first material including a phase (liquid, solid or gas) substantially absent from the second material, and is characterised in that the tube projects forwardly of the pipe. Preferably the second material is under great pressure in its pipe, and/or moves faster, than the first material in its tube. Preferably the exit of the tube is such that the first material, on leaving the exit, has a nil or negative component of momentum radially outwardly of the tube axis. The exit preferably comprises a plurality of orifices. Each orifice is preferably such a small proportion of the total exit as by itself to have no substantial effect on the flow of the erosive jet.

The first and second materials can each independently be liquid or gas, and the first material preferably further comprises a solid. In one preferred version, the first material is a mixture of fluid plus solid and the second material is fluid, the fluid conveniently being the same in both materials, for example water or air. Alternatively, the first material can be gas (e.g. air), or liquid entraining a substantial proportion of gas bubbles, while the second material is liquid (e.g. water).

The distance by which the tube projects forwardly of the pipe is preferably at least five times, more preferably at least ten times, the radial extent of the annulus defined between the downstream end of the pipe and the outer wall of the tube at that point. Where the tube exit comprises a plurality of orifices, every orifice must be forward of the pipe.

The tube exit is preferably of conical form, with orifices formed parallel to or converging towards the axis, preferably of cylindrical form. While the conical form may be stepped or frustrated, such should not be on a scale that would substantially disturb the flow.

Multiple pipe-and-tube assemblies are possible, or several tubes in one pipe.

The invention will now be described by way of example with reference to the accompanying drawings, of which Figures 1 and 2 each show apparatus in schematic elevation for forming a jet by a method according to the invention, and Figure 3 shows to an enlarged scale a detail of the Figure 2 apparatus.

Turning to Figure 1, a slurry tube 1 supplies a dense abrasive slurry 2 ('first material') to a gently convergent orifice 3, at a speed low enough to avoid erosion of the tube 1. Meanwhile, water 4 ('second material') is directed in the same sense as the slurry but at much higher speed through a convergent pipe 5, which is coaxial with, and surrounds, the slurry tube 1. The slurry tube 1 however projects forwardly of the pipe 5, by five times the radial distance between the outer wall of the tube 1 and the inner wall of the pipe 5. (If the pipe 5 ended in the same plane as the orifice 3, an unstable divergent spray would be obtained.) For simplicity, Figure 1 shows the tube 1 slightly less projecting than described. As the pipe 5 is more convergent than the tube 1, a facility for projecting/retracting the tube 1 has the effect of acting as a valve for the pipe 5.

In use, the water 4 at high pressure continues to converge under the action of its inward momentum. The water velocity profile is thus matched to take the relatively slow-moving axially-introduced slurry 2. Mixing then occurs gradually (over a distance of many orifice diameters) such as to form a parallel-sided intermediate-speed erosive jet. As the mixing occurs outside any hardware, erosion of the apparatus is kept to a minimum.

In Figure 2, a convergent pipe 25 conveys a stream of water 24 from a 10 m-high header tank in a quarry. An inner tube 21 conveys water from the same header tank but at a reduced pressure (a gate valve being included in the supply to the tube 21), and blended in a mixer tank with the finer sievings of grit arising from the quarry to form an abrasive slurry. The grit makes up about half (by weight) of the material in the tube 21; there is no grit in the pipe 25. The gate valve is set so that the mass flux through the pipe 25 is from ten to twenty times the mass flux through the tube 21, whereby grit makes up about $2\frac{1}{2}$ to 5% of the total mass flux.

The pipe 25 has an exit in the form of a multi-orifice cone 23. Each orifice 27 is very slightly convergent towards the axis, although orifices all parallel to the axis also give good results. Note that even the most upstream orifice is well proud of the pipe 25.

The slurry passes through the orifices 27 at

insufficient speed to erode the cone 23 significantly, at a pressure of almost nil gauge. The grit is of course sieved to a size well under the orifice diameter.

Each orifice 27 is parallel-sided. It may have a square, round, elliptical, crescent or other cross-section, in this example having a circular cross-section, such as would arise from drilling the cone 23. As more clearly seen in Figure 3, the orifice 27 maintains its cross-section even on the surface of the cone 23, which has a near-elliptical depression 28 which is the parallel-sided (cylindrical) orifice 27 geometrically produced. This depression 28 has the effect of permitting the abrasive slurry from the tube 21 passing out of the orifice 27 to remain convergent towards the axis of the apparatus as it emerges (shown schematically in Figure 2) and also encourages the slurry to fan out slightly around the cone 23. With many orifices, axially and circumferentially distributed all over the cone, the slurry is smoothly bled into the stream of water 24 without disturbing its flow. The cone 23 contains as many orifices 27 as can practically be formed in it.

There results a jet of an erosive power that could otherwise be achieved only with a slurry pump developing a pressure of more than 10 m-head of water. Fine grit resulting from quarrying with this jet, and run-off water, are cycled up to the mixer tank and the header tank respectively. The raw materials for the erosive jet are thus in effect 'free', and an unsophisticated lifting pump or bucket feed suffices as the power, which need not even be available all the time, depending on the tank capacities.

The cone 23 was made by drilling orifices into a conical blank, but alternatively could be made by constructing a 'negative', i.e. defining a conical space in a solid and transfixing the space with rods (representing the desired orifices), then casting the transfixed space in wax and continuing by conventional lost-wax casting techniques. Another manufacturing possibility is to assemble a bundle of parallel fine tubes, braze them together, and form a conical shape by decapitating the bundle with a 'pencil-sharpener' action.

CLAIMS

1. A method of forming an erosive jet, comprising supplying a first material through a tube to an exit, directing a second material in the same sense as the first material through a convergent pipe generally coaxial with and surrounding the tube, at least one of the materials being a fluid, the first material including a phase substantially absent from the second material, the method being characterised in that the tube projects forwardly of the pipe.

2. A method according to claim 1, wherein the second material is under greater pressure in its pipe, and/or moves faster, than the first material in its tube.

3. A method according to claim 1 or 2, wherein the exit of the tube is such that the first material, on leaving the exit, has a nil or negative component of momentum radially outwardly of the tube axis.

4. A method according to claim 3, wherein the exit comprises a plurality of orifices (all of which are forward of the pipe).

5. A method according to claim 4, wherein each orifice is such a small proportion of the total exit as by itself to have no substantial effect on the flow of the erosive jet.

6. A method according to any of claims 1 to 3, wherein the distance by which the tube projects forwardly of the pipe is at least five times the radial extent of the annulus defined between the downstream end of the pipe and the outer wall of the tube at that point.

7. A method according to claim 6, wherein the said distance is at least ten times the said radial extent.

8. A method according to claim 4 or 5, wherein the tube exit is of conical form, with the orifices formed parallel to or converging towards the axis.

9. A method according to any preceding claim, wherein the first material is a mixture of fluid plus solid and the second material is fluid.

10. A method according to any of claims 1 to 8, wherein the first material is gas, or liquid entraining a substantial proportion of gas bubbles, and the second material is liquid.

11. A method of forming an erosive jet, substantially as hereinbefore described with reference to and as shown in Figure 1, or Figures 2 and 3, of the accompanying drawings.

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